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ENRICHMENT OF LITHIUM IN NORWEGIAN CLEAVELANDITE-QUARTZ-PEGMATITES

BY

IVAR OFTEDAL

Abstract. All the Norwegian cleavelandite-quartz-pegmatites from which suitable material was available are shown to be enriched in lithium. In nearly all of them is found a brownish mica related to zinnwaldite and containing more than 1 %, in extreme cases more than 3 %, Li_2O. Other Li-rich minerals (petalite, spodumene, amblygonite &c) have so far not been observed in these deposits.

Minerals containing appreciable amounts of lithium appear to be particularly rare in Norway. A real lithium mica from Lille Årøy in the Langesundsfjord has been described by W. C. Brøgger.[1] The percentage of Li_2O in this mica is not given by Brøgger, as the material available was insufficient for a chemical analysis. By the method described below I found that the mineral must contain a percentage of Li_2O similar to that of the polylithionite from Kangerdluarsuk in Greenland, which is about 9 %.[2] This is still the Norwegian mineral with the highest known content of Li, but it is extremely rare and therefore does not contribute appreciably to the amount of Li present in the Langesundsfjord pegmatites. So does, however, the lepidomelane, which occurs in large quantities. L. W. Strock[3] found in the lepidomelane from Låven nearly 0.7 % Li_2O. My own results agree well with this figure. At the same time they show that lepidomelane from other localities in the Langesundsfjord may be somewhat poorer in Li_2O.

During spectrographic examination of minerals from the collections of the Mineralogisk-geologisk Museum in Oslo I found that also micas from certain Norwegian granite pegmatites show considerable contents of Li. These pegmatites are all of the (hydrothermal-pneumatolytic)

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[1] Zeitschr. Kryst. *16*, 1890, 195.

[2] J. Lorenzen, Medd. Grønland, *2*, 1881, 71 and *7*, 1893, 13. This supports Brøgger's assumption that the mineral is related to polylithionite.

[3] Zur Geochemie des Lithiums. Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl., Neue Folge, *1*, 1936, 185. Here is also reported that an inclusion of essexite lava in nepheline syenite pegmatite from Låven was found to contain 0.5–1.0 % Li_2O

cleavelandite-quartz type. The examined material has been collected and described by H. Bjørlykke.[1] As his investigations were carried out by means of X-ray spectral analysis he could not, of course, detect contents of Li in the minerals. As the presence of lithium mica is to be expected in cleavelandite-quartz-pegmatites[2] Bjørlykke also examined the colouring of the flame produced by a lilac coloured mica from such of deposit (Birkeland 2, Iveland), with negative result.[3] The optical spectograms confirm that this particular mica is poor in Li, in fact not richer than ordinary muscovites. The spectograms of other (brown to greenish) micas from similar deposits, however, show very strong lines of Li, and the carbon arc gives a very conspicuous red light during the first few seconds of the evaporation of these micas. This behaviour is distinct from that of all the examined ordinary micas (muscovites, biotites, phlogopites), the spectograms of which show only very weak lines of Li. The enrichment of Li in micas of Norwegian cleavelandite-quartz-pegmatites thus being recognized, it was found of interest to attempt a quantitative spectrographic determination of the percentages of Li_2O in these micas. As it is of importance that the standard mixtures should possess as nearly as possible the same properties as the examined minerals, they were in this case prepared by mixing together ordinary muscovite (containing less than 0.1 % Li_2O) and a lithium mica whose content of Li was known with some certainty.[4] For such a lithium mica was chosen the above mentioned polylithionite from Kangerdluarsuk, which, according to the published analyses, contains about 9 % Li_2O. Of course it can not be taken for granted that the particular sample used contains exactly this amount of Li_2O, however, the standard mixtures obtained were chequed by means of spectra of lepidolites (Rozna, Mähren and Paris, Maine) and zinnwaldite (Zinnwald), for which a number of analyses are found in the literature, and a fairly good agreement was found. Therefore these standard mixtures were considered fairly reliable. They were made to contain Li_2O in

1 N. G. T. *14*, 1935, pp. 226, 227, 241, 242 and N. G. T. *17*, 1937, 14.

2 K. K. Landes, Am. Mineralogist, *18*, 1933, 50.

3 N. G. T. *14*, 1935, 248.

4 A series of mixtures prepared by mixing together muscovite and kunzite (assumed to contain about 7 % Li_2O) proved to be not very suitable for the determination of Li in micas. Kunzite obviously does not give off Li in the same way as do the micas during the evaporation in the carbon arc.

concentrations from about 9 % down to about 0.1 %. As it was convenient to use the Li-line 3232.7 (the lines in the visible spectrum being far too strong), the spectra were taken with the quartz spectrograph in the ultraviolet. This Li-line does not coincide with any other lines of importance in the present case. Electrodes of purified carbon were used, the cathode with a bore 4 mm deep and 1.5 mm in diameter, which was filled with the substance to be evaporated. The arc was kept burning at about 5 A for 2 minutes, the cassette and slit being open all the time. At the end of this exposure the evaporation of the sample was almost complete, only a minute bead being left in the cathode. From watching the colouring of the arc light it appears that the alkalies evaporate almost completely during the first minute, the aluminium (and iron) usually before the end of the second minute. The remaining bead usually gives no colouring of the light at all, and therefore probably consists of nearly pure SiO_2. It would seem, therefore, that the Al-lines will afford fairly reliable intensity standards for comparison with the Li-line. It is true that the percentage of Al may vary considerably in the different micas, however, it was found that the Al-lines show very nearly the same absolute intensities in all the spectra in question, and that a fairly evenly sloping calibration curve for the pair Li 3232.7—Al 3082.2 could be constructed from the spectra of the standard mixtures. This curve seems to give good values for micas poor in Mg and Fe, like the majority of the examined ones. In the case of e. g. lepidomelane a correction must be made for the low content of Al, or the Li-line may be compared with a Si-line. In order to make possible a closer intensity comparison and the construction of the calibration curve all the spectra were stepped by means of a rotating sector giving exposure times in the proportions 1 : 2 : 4 : 8 : 16 : 32 : 64. The use of the photometer was dispensed of,[1] as a visual intensity comparison in this case is sufficiently exact in view of the uncertainty as to the accurate percentage of Li in the polylithionite used for the standard mixtures. For this reason the figures given below are to be taken as approximately correct only. The following list contains the percentages of Li_2O found in micas from cleavelandite-quartz-pegmatites.

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[1] L. W. Strock, Spectrum Analysis with the Carbon Arc Cathode Layer, Adam Hilger, Ltd., London, 1936, 43. For a description of the spectrographic methods applied reference may be made to this paper in general.

Landås, Iveland:

Brown mica from specimen with cleavelandite, quartz and microlite	1.5 %	Li_2O
Muscovite in large flakes	0.2 »	»
Olive green mica	<<0.1 »	»

Katterås, Iveland:

Light greenish brown mica from specimen with cleavelandite, quartz and topaz	1.5 »	»

Skripeland, Iveland:

Light brownish mica from specimen with cleavelandite, quartz and topaz	1.5 »	»

Birkeland 2, Iveland:

Yellowish green mica from specimen with cleavelandite, quartz and topaz	0.2 »	»
Lilac coloured mica from a second specimen with cleavelandite, quartz and topaz	<0.1 »	» [1]

Mørkhøgda, Gjerstad:

Yellowish mica from specimen with cleavelandite, quartz, beryl and tourmaline	0.1 »	»

No other minerals containing appreciable amounts of Li were found in this material. As mentioned above, the micas from all other kinds of deposits in Norway (not counting the pegmatites of the Langesundsfjord region) seem to be poor in Li. In all of the following specimens the contents of Li_2O were found to be below or about 0.1 %.[2]

Muscovite from ordinary (magmatic) granite pegmatites	Tveit, Iveland.
	Arendal.
	Sigdal.
Mica from greisen	Glitrevann, Modum.

[1] This mica occours in rather large quantities in the deposit and has been supposed to be a lepidolite. Bjørlykke, as mentioned above, found that it is not a lithium mica. Also Barth (N. G. U. *128 b*, 140, 1931) states that the lilac coloured mica from Birkeland is a muscovite, not a lithium mica.

[2] L. W. Strock (Zur Geochemie des Lithiums, l. c. pp. 184, 185, 187) found the following contents of Li_2O: Phlogopite 0.016 %, meroxene 0.022 %, muscovite 0.043 %, biotite (Iveland) 0.13 %.

Biotite from granite pegmatite	Tveit, Iveland.
	Ljosland, Iveland.
Phlogopite from apatite deposit	Ødegården, Bamble.
Biotite from micaschist.....	Fossingfjord, Bamble.

The muscovite from Thoreby, Varteig contains about 0,3 % Li_2O, indicating a moderate enrichment of Li in this pneumatolytic deposit. The enrichment of Li in the cleavelandite-quartz-pegmatites, which was to be expected as a consequence of the late formation of these deposits, is very clearly shown by these data. Some of the micas (see Landås, Katterås, Skripeland) are in fact nearly as rich in Li as some of the zinnwaldites from other countries. The relation to zinnwaldite is made still closer by their considerable contents of iron. On the other hand these pegmatites may at the same time contain micas which are not particularly enriched in Li (see Landås, Birkeland). In some cases the enrichment of Li in the deposit as a whole seems to be less prominent (Birkeland, Mørkhøgda).

High concentrations of Li in the micas are commonly accompanied by relatively high contents of Rb and Cs, as can be seen in spectra taken in the visible region. This is known also from earlier examinations of lithium micas.[1] Another conspicuous feature of the Li-rich micas from the cleavelandite-quartz-pegmatites is their usually very high content of Mn as compared with e. g. ordinary muscovites, even if the contents of Fe are not essentially higher than those of the muscovites.

In addition to this material collected by Bjørlykke similar specimens very found among samples collected by Olaf Andersen in 1909 and labelled Frikstad, Iveland. As a large number of granite pegmatites are found within the area of Frikstad it is not possible to tell the exact locality. Possibly it is one of the small quarries at "Kjørka", in which cleavelandite is known to occur.[2] A brown mica, looking very like that from Landås, from a specimen consisting chiefly of cleavelandite, was examined. It was found to be still richer in Li

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[1] See e. g. Doelter, Handb. d. Min.-Ch., II, 2, 1917, 456. Also Tl, which has been found in lepidolite, was observed in some of the spectra of Li-rich mica from Iveland, probably in concentrations of the order of magnitude 0.01 %. The contents of Ga were found to be, on the average, not higher in the Li-rich micas than in ordinary muscovites.

[2] Tom. F. W. Barth, N. G. U., *128 b*, 139, 1931.

than any of the micas listed above, the content being about 3 % Li_2O. Like the other Li-rich micas from Iveland it contains some Fe and much Mn and is obviously a zinnwaldite. Other Li-rich minerals were not found in the specimens from Frikstad. A green mica associated with ordinary albite contains not more than 0.1 % Li_2O.

Quite recently still another occurrence of Li-rich mica has been found in the Archaean of Southern Norway. The occurrence became known through specimens which have been given to the Mineralogisk-geologisk Museum in Oslo. So far I have not been able to examine the deposit itself; the closer description, therefore, has to be postponed until later. Here I may only mention that the mica is richer in Li than any of those from Iveland, and otherwise closely related to them. In fact it is real lithium mica, the spectrograms indicating in some samples about 4 % Li_2O. In addition it occurs in much larger quantities than the Li-rich micas from Iveland. It can be seen from the specimens that the deposit is a pegmatite of the cleavelandite-quartz type. It is to be expected that also other Li-rich minerals will be found in the deposit.

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